Soil Quality Criteria Relative to Disturbance and Reclamation

Revised

March, 1987

Alberta
AGRICULTURE

SOIL QUALITY CRITERIA

RELATIVE TO

DISTURBANCE AND RECLAMATION

(Revised)

Prepared by the

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1. INTRODUCTION

Land disturbances due to resource extraction and transport are intended to be only temporary disruptions to the normal use of land for food and fiber production or for recreation. Although no two sites are identical, many disturbances cause similar types of problems and concerns but in varying degrees of intensity. Assurance such disturbances are temporary is possible only if information concerning the site is well documented and an appropriate reclamation program planned prior to disturbance. Evaluation of the nature of materials at hand prior to disturbance and subsequent to reclamation, however, requires criteria by which to assess the quality of those materials. To this end a Soil Quality Criteria Subcommittee of the Alberta Soils Advisory Committee was formed in 1978 with the terms of reference being to develop criteria relative to:

1. soil mapping and sampling for baseline and post disturbance activity;
2. overburden sampling;
3. analytical requirements;
4. physical, chemical, and biological criteria for evaluating the suitability of soil materials for revegetation; and
5. utilization of soil as a medium for waste disposal including materials such as sewage sludge, animal wastes, and fly ash.

The following responsibilities became part of the purview of the subcommittee. The

1. preparation of a glossary of soil terms and a bibliography relevant to the above subject matter;
2 delineation of the province into broad ecological zones so relevant guidelines and criteria could be established for the major regions; and
3. development of recommendations for future action and research.

A report was prepared, reviewed by the Alberta Soils Advisory Committee, and published in 1981 under the title "Proposed Soil Quality Criteria in Relation to Disturbance and Reclamation". During the intervening four years, it has received considerable attention and many constructive suggestions for revision. Where new information, or more complete interpretations of earlier data have been available, revisions have been made.

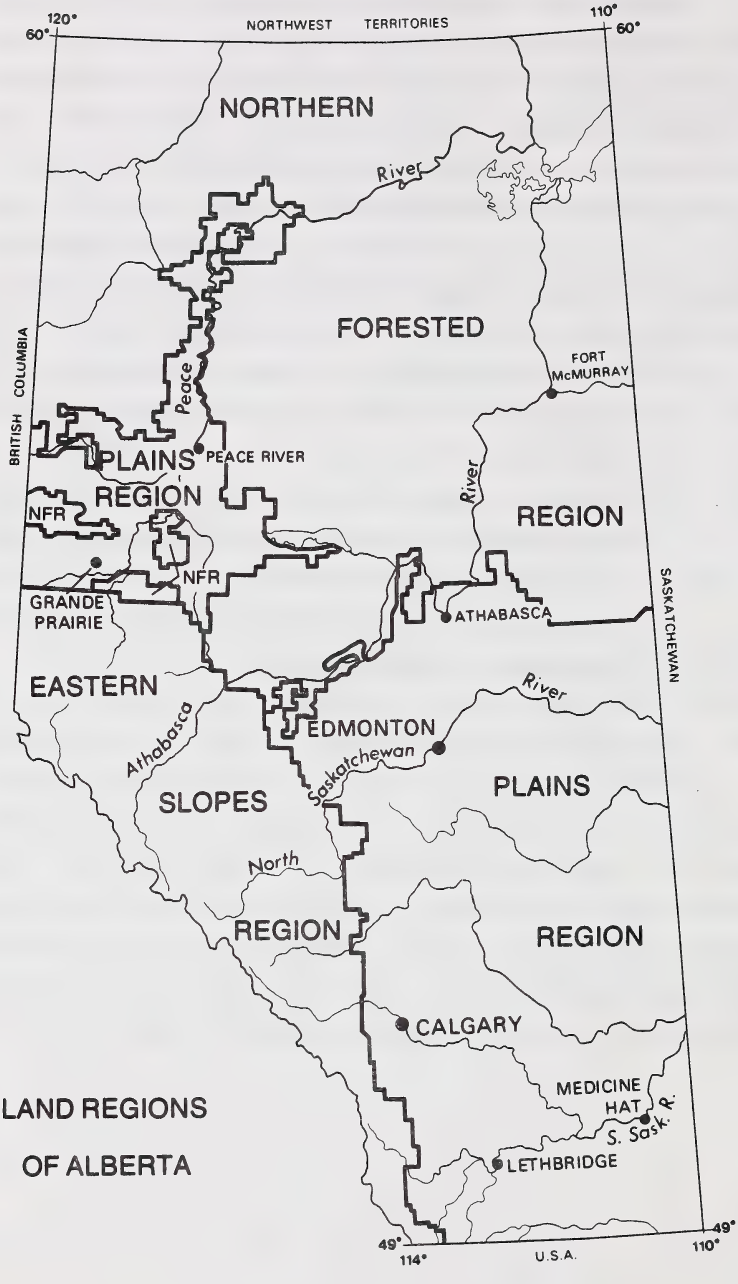
The report that follows deals with the first four terms of reference, and has benefitted from consultation with many Soil Scientists, Pedologists, and others involved in reclamation. The subcommittee did not address the term of reference dealing with soil quality for waste utilization as provincial guidelines governing wastewater and sludge application to soil presently exist. The subcommittee is aware that a number of government agencies are involved in regulating the selection and operation of landfill sites and other waste disposal emplacements.

The report is meant for use as a guide to assist people involved in a professional capacity in land reclamation. Reclamation technology and soils research are continually progressing. Consequently ongoing consultation, revision and updating of this publication is expected as more data become available. This is a scientific, technical manual for use by professionals. It therefore contains no reference to policies or regulations of any government agency nor does it address economic, social or political issues. Economic and political decisions must make use of quality criteria, but the criteria themselves are independent of such considerations.

2. THE MAJOR REGIONS OF THE PROVINCE

The province was divided into three distinct regions (Figure 1) in an attempt to establish criteria that would apply to each area in general. It is true that there are differences within each of these regions, but it is beyond the scope of this document to suggest criteria for subdivisions of each of the three major regions. Individual operations within each of the major zones will have unique conditions or characteristics resulting in specific problems and requirements. Therefore specific criteria requirements must be handled on a site by site basis. The three major regions are the:

1. Plains Region which includes the Central Plains and Peace River Plains, and has a predominantly agricultural land use;
2. Eastern Slopes Region which includes the Lower and Upper Foothills and the Rocky Mountains to the British Columbia border; and
3. the Northern Forested Region which includes the remainder of the province.



LAND REGIONS

OF ALBERTA

Figure 1

3. SOIL SURVEY AND SAMPLING

3.1 INTRODUCTION

It is important to understand the soil relationships in an area prior to preparation of a development plan in order to ensure adequate evaluation of the potential for reclamation. A soil survey with relevant interpretations is one of the first steps to be taken. The soil survey is planned and conducted to provide the level of information required for activities such as materials handling and soil reconstruction. The following section describes mapping and sampling techniques to be employed to conduct soil surveys.

3.2 SOIL SURVEY

3.2.1 Design

A soil survey is planned or designed on the basis of a sequence of decisions (Expert Committee on Soil Survey (ECSS) 1981). These decisions are listed and discussed below.

1. Establish the objectives of the survey. The objective of baseline soils mapping in this context is to provide information on the types of soil present, in sufficient detail, that decisions regarding materials handling and post disturbance soil reconstruction can be made. The information also provides a basis for formulating interpretations or predictions relative to post disturbance land use.
2. Determine the smallest area in the field that must be described and delineated to meet the objectives of the survey. The minimum size delineation is generally considered to be the smallest delineation inside which a simple symbol can be printed or the smallest area which can be discerned by a map user. The ECSS (1981) recommends that a practical minimum size delineation on a soil survey map is one-half of a square centimetre.

3. Determine the survey intensity level (SIL). SIL is defined and controlled by the number of field inspections per unit area or other estimates of accuracy. Generally speaking, the number of field inspections increases with the detail of survey. The SIL involves implications of inspection densities, scale, survey techniques, levels of soil taxonomy used and accuracy of boundaries. Five survey intensity levels are proposed in Canada (ECSS 1981) but only Levels 1 and 2 are described in Table 1 as they reflect the amount of precision required for working with soils in the context of this report. On the basis of research conducted in Montana, Schafer (1979) suggests that order 2 (1:12 000 to 1:30 000) soil surveys are useful for general planning but must be supplemented by order 1 (1:10 000 scale) maps for purposes of cover-soil selection. For the purpose of this report it is suggested Level 2 surveys be conducted to provide a mechanism for general planning and that more detailed work be conducted where necessary depending upon the type of surface disturbing activity and the associated needs. Table 1 provides suggested scale limits for the two intensity levels defined and Table 2 provides recommended scales for mapping. The scale of mapping is largely based on the minimum size of field delineation. For example, if soil units with different use potentials must be recognized down to a size of 4 ha then the scale should be at least 1:20 000.

   Table 2 indicates that Level 2 surveys are conducted for the purpose of providing baseline or general planning surveys in the three regions of the province. In these three major regions there are different factors which must be considered. For example, in the

Table 1. Criteria for identifying survey intensity levels[1].

Survey Intensity Level (SIL)	Common Name	Definitive Characteristics		Associated Features		Appropriate Scale (Usual)[3]
		Inspection Intensity	Methods of Investigations	Main Kinds of Soil Components	Map Units[2]	
SIL1	very detailed	At least one inspection in every delineation (1 per 1-5 ha). Boundaries observed throughout entire length (over 50% in wooded area).	Transects and traverses less than 0.5 km apart. Profile descriptions and samples for all soils.	Series or phases of series	Mainly simple units	1:14 000 or larger (1:5 000)
SIL2	detailed	At least one inspection in 90% of the delineations (1 per 2-20 ha). Boundaries plotted by observations and interpretation of remotely sensed data verified at closely spaced intervals.	Transects and traverses less than 1.5 km apart. Profile descriptions and analyses for all major soils	Series or phases of series	Simple and compound units	1:5 000 to 1:40 000 (1:20 000)

1 Adapted from a Soil Mapping System for Canada: Revised (ECSS 1981).

2 Simple units have over 80% of a single component or a nonlimiting inclusion. Compound units are complexes or associations of two or more components.

3 Appropriate publication scale.

Table 2. Guidelines for conducting soil surveys relative to development and reclamation.

Region	Purpose of Mapping	Level of Survey	Recommended Publication Scale	Min. Size Area Represented by 1 cm^2 on Map (ha)	Inspection Density (ha/Insp)	Sampling Density (Profile, Sites) ha/Sample	Overburden Sampling ha/Sample Site
	Baseline	2	1:10 000	1	1 to 5	10 to 50	150 to 300
Plains	Post Disturbance (Nonselective Handling)	1	1:5 000	0.25	0.25 to 1.25	1.25 to 6.25	-
	Post Disturbance (Materials Handling)	1	1:10 000	1	1 to 5	10 to 50	-
	Baseline	2	1:10 000	1	1 to 5	10 to 50	150 to 300
Eastern Slopes	Post Disturbance (Nonselective Handling)	1	1:5 000	0.25	0.25 to 1.25	1.25 to 6.25	-
	Post Disturbance (Materials Handling)	1	1:10 000	1	1 to 5	10 to 50	-
	Baseline	2	1:10 000	1	1 to 5	10 to 50	150 to 300
Northern Forest	Post Disturbance (Nonselective Handling)	1	1:5 000	0.25	0.25 to 1.25	1.25 to 6.25	-
	Post Disturbance (Materials Handling)	1	1:10 000	1	1 to 5	10 to 50	-

Plains Region one would probably concentrate on parameters such as depth of topsoil (Ah horizon) and the presence or absence of Solonetzic soils. In the Eastern Slopes Region parameters such as total depth of soil material overlying bedrock and coarse fragment content would be of concern. For post disturbance mapping a scale of 1:5000 is suggested for non-selectively handled areas or those areas where materials handling techniques were minimal. Where materials handling techniques (selection and salvage of materials) were employed a scale of 1:10 000 is recommended.

4. Determine the inspection density in relation to the scale and purpose of the survey. Inspection density is related to the amount of ground truth (digs or observations) that is required. An "observation" or "dig" can be defined as a ground truth that the pedologist can use as a control point to extrapolate his or her mapping. This usually means a soil exposure by shovel or auger, but could range up to a fly-past in the case of rock outcrop. Inspection density provides some measure of the reliability of a soil map. Generally speaking, for a reasonably reliable soils map there should be one dig or inspection per sq cm on the map (ECSS 1981). An acceptable range might be 0.2 to 2 inspections per sq cm. The concept of 1 inspection per sq cm is based on an average for the specific project. In areas where soils are easily interpreted from soil landscapes, or from aerial photographs, the inspection density could drop by a factor of 5 or 10 from the level of 1 per sq cm on the map.

The number of inspections per area of land varies with the detail of the survey. Therefore, inspection density must be closely tied to and related to scale.

Table 2 provides suggested inspection densities relative to recommended scales based on an inspection density of 1 to 5 ha per inspection.

For linear disturbances such as pipeline rights of way in agricultural areas, the inspection density is the number of soil inspections made relative to the length of the right of way. For a soil evaluation done for problem (solonetzic or saline) soils or problem parent materials, the inspection density is between two to five inspections per kilometre. For ground truthing in areas where existing information from soil surveys and geology maps indicates there will be no problem soils or problem parent materials, the inspection density is one site per kilometre.

3.2.2 Soil Profile Characteristics and Landscape Features

Soil mapping involves the recognition of soil profile characteristics and landscape features. The profile characteristics normally observed and recorded include:

1. horizon thickness and sequence;
2. colour;
3. texture;
4. structure;
5. consistence;
6. effervescence and salt crystals;
7. coarse fragments;
8. field pH (not required for all observation sites);
9. presence of mottles; and
10. roots.

The parameters observed in completing a site description include the following:

1. slope class (topography);
2. aspect;
3. landform;

4. surface stoniness;
5. surface and internal drainage;
6. extent of erosion;
7. present land use (as related to delineating soil types); and
8. vegetation cover - trees, shrubs, herbs, grasses, and mosses (as related to delineating soil types).

Not all of the above parameters need be recorded for each site inspected, however, they should be documented for each profile sampling site. Furthermore, the parameters recorded will vary to some extent relative to the type of disturbance involved.

3.2.3 Map Presentation

The soil survey information should be presented on an aerial photo mosaic base. With the relatively large scales involved, location and orientation are superior compared to line drawn or colour coded maps. Because the landscape is illustrated, interpretations are easier to make. Use of the photo mosaic base is particularly helpful in working with post disturbance landscapes.

3.3 SOIL SAMPLING

The methods of sampling vary with the purpose for which the samples are required. For example, sampling in conjunction with predisturbance mapping may involve emphasis on different parameters than sampling of disturbed areas.

Sampling intensity is largely dependent upon the scale of mapping employed and the variability of the soils encountered in the survey. A less intensive sampling program would be appropriate in areas where the materials are relatively homogeneous.

3.3.1 Sampling for Baseline Evaluation Purposes

The number of sampling sites selected should be determined primarily by the frequency of occurrence of the individual map units.

Adequate numbers of samples should be collected to properly characterize the various map units (Table 2).

In the case of baseline mapping the samples are collected for purposes of characterization and classification. For this reason sampling intensity refers primarily to sampling of soil pits. However, some "grab" samples of surface materials may also be collected for characterization purposes and are included in the overall recommended number of sampling sites. It is suggested that for baseline purposes at least 50% of the sampling sites include sampling the entire soil profile.

Table 2 provides a range in the sampling density required for a particular scale. For example, for a Level 2 survey conducted at a scale of 1:10 000, a sampling density ranging from 10 to 50 ha per sampling site is recommended. In mapping for baseline or evaluation purposes an overall sampling density of 30 to 50 ha is probably adequate.

3.3.2 Methodology of Sampling for Baseline Purposes

The following provides a suggested procedure for sampling as part of a soil survey for baseline or evaluation purposes:

1. select sample sites typical of the soils that the samples are intended to represent (McKeague 1978);
2. the sites should be away from fences, roads, and other features that may cause atypical properties;
3. samples should be collected from freshly dug pits and not from roadcuts. The pit should be deep enough to expose part of the C horizon, or to the bottom of the control section (CSSC 1978), whichever is deeper.
4. sample on a horizon or "homogeneous layer" basis and from a face about 50 cm wide for laterally uniform soils. If horizons are discontinuous, vary greatly in thickness or degree of expression, collect samples from different locations on the pit face to ensure a representative sample of each horizon is obtained.

Some discontinuous horizons may not be significant enough in amount or characteristics to warrant sampling and analysis; and

5. if possible, start sampling at the bottom of the pit.

3.3.3 Overburden Sampling (2 m + Depth)

The preceding section dealt with sampling the soil control section which in the case of mineral soils generally involves a depth of 1 to 2 m. The material below the control section and above the resource to be extracted can be referred to as overburden.

Overburden sampling should be based on the lithology of the area. Selection of appropriate sites should be based on soils and geologic information. Surficial and bedrock geologic information is available for most areas of the province.

Overburden samples should be collected in increments:

1. not exceeding 0.5 m in the 2 to 5 m depth; and
2. not exceeding 1.5 m in the 5 m depth to the top of the resource except in areas where the formations or materials are known to be relatively uniform. A less intensive sampling would be appropriate when geologic conditions are generally known and especially in areas where the overburden is known to be unsuitable.

3.3.4 Sampling Post-Disturbance Areas

Guidelines in the literature vary widely with regard to the number of samples to be collected in order to adequately characterize reconstructed soils. As noted for baseline sampling programs, frequency of sampling also depends on the purpose for the sampling. Table 2 offers guidelines with regard to sampling frequency for nonselectively handled areas and areas where materials handling was employed. The values in the table indicate a greater frequency of sampling for nonselectively handled areas as compared to those where selective materials handling was employed because of the more heterogeneous nature of the former. The sampling frequency includes

site sampling down to the depths described later in this report as well as grab samples of the surface material.

Sampling of reconstructed soils should be done on the basis of layers or materials such as topsoil, subsoil, and spoil and on depth intervals within each of these discrete layers. Table 3 provides an indication of the total depth and intervals that should be sampled in reconstructed soil areas. The depth of sampling is wholly dependent on the type of material encountered. For example, in the Eastern Slopes Region the shallow layer of soil material over rocky spoil will, in some instances, limit the sampling procedures.

3.3.5 Transporting and Processing Samples

There are a number of factors to be considered when transporting and processing soil samples.

1. Polyethylene plastic bags should be used for transporting samples from the field. Paper bags are not recommended.
2. Galvanized equipment should be avoided if zinc is to be determined.
3. Moist samples to be analysed for nitrate or ammonium nitrogen cannot be stored under warm conditions.
4. For best results moist or wet samples are immediately frozen or spread to dry on waterproof material. Once dry they are ground to 2 mm sized fragments and stored in closed, water-tight containers.

Table 3. Sampling depth intervals for reconstructed soils in the three regions.[1]

Region	Depth Interval (cm)	Notes
Plains	0 to 15 or 15 to 30 30 to 45 45 to 60 60 to 90 90 to 120 120 to 150	The topsoil layer should be taken in one sample. If topsoil depth is less than 15 cm then that depth of material should be segregated from material below. If topsoil is greater than 15 cm then first sample can exceed 15 cm in thickness. If topsoil layer is greater than 20 cm in thickness topsoil should be split into two sample intervals. Sample should be collected to and including one depth increment of spoil if depth to spoil is greater than 1.5 m.
Northern Forest	0 to 15 15 to 30 30 to 60 60 to 90 90 to 120	If the upper lift is less than 30 cm in thickness it could be sampled in one or two intervals. For example, if 20 cm thick then one sample interval would be appropriate, if greater than 20 cm thick it should be split into two samples. Samples should be collected to and including one depth increment of spoil if depth to spoil is greater than 1.2 m.
Eastern Slopes	0 to 15 15 to 30 then 30 cm increments where possible to 120 cm	If the thickness of replaced soil material is less than 30 cm then sampling could be done in one or two intervals. For example, if 20 cm thick then one sample interval would be appropriate, if greater than 20 cm thick the recommended intervals should be utilized.

[1] Sampling should be conducted on the basis of the layers replaced and depth intervals within these layers.

4. ANALYTICAL REQUIREMENTS

Analytical requirements have been separated into two sections: those required for baseline characterization (Table 4) and those required for disturbed and orphaned areas (Table 5). The analyses listed aid in properly characterizing soils for classification and mapping purposes and making interpretations relative to the quality of the soils as they occur in the undisturbed and reconstructed states. They also assist in developing predictions about the degree of usefulness they may have in the post disturbance situation.

Primary emphasis is placed on particle size distribution and identifying materials which are unsuitable due to unfavourable levels of salinity, sodicity or pH. Fine textured sodic and saline-sodic materials are common in Alberta and can restrict plant growth when they occur at or near the surface.

Analyses to quantify other soil characteristics are required with a lesser frequency. Cation exchange capacity, total nitrogen, total carbon and macronutrient analyses can be useful in assessing the availability and mobility of some nutrients. Extractable aluminum and manganese analyses are useful on low pH soils to aid in assessment of toxicities.

Where possible, McKeague (1978) was cited for the methods of soil analyses. The suggested methods have reasonable levels of precision and accuracy.

Table 4. Minimum analytical requirements for baseline characterization - all regions.

Analysis required on all samples.

Analyses	Notes	Preferred[1] Method	Acceptable Method
pH	If one is interested in soil pH only method 3.11 provides a number of advantages (p. 66 of McKeague). However, the saturation extract (method 3.14) is also used for EC and soluble ion analysis.	3.14 or 3.11	3.13
Saturation[2] Percentage	(i) Samples which need to be resaturated after equilibrating for four hours may be resaturated but must be equilibrated for a further four-hour period prior to extraction. This step may have to be repeated several times to achieve saturation. (ii) If the saturated soil cannot be filtered under normal vacuum, make a note of this and report the pH and saturated % only.	3.21	
Electrical Conductivity[2]		3.21	
Soluble Cations[2] (Ca, Mg, Na, K) and SAR		3.21	
Particle Size Distribution		2.11	2.12

[1] McKeague, J.A. 1978. Manual on soil sampling and methods of analysis. Canadian Society of Soil Science. Ottawa, Canada.

[2] **In profiles where there is no evidence of salinity and sodicity these analyses are not required on the A and B horizons but are required on a selected number of other samples. In the Northern Forested and Eastern Slopes Regions a lesser number of overburden samples need be analysed for salinity and sodicity parameters.**

continued . . .

Table 4. Continued.

Analyses required on selected samples from two representative profiles (A and B horizons only) per major map unit.

Analyses	Notes	Preferred[1] Method	Acceptable Method
Total Nitrogen[1]		3.622/3.624	3.621/3.623
Organic Carbon[1]		3.611	3.612/3.613
Cation Exchange[2] Capacity	Not required for samples containing free carbonates or crystals of soluble salts	Methods of Soil Analyses, Agronomy No. 9 2nd Edition[3]	3.32
Exchangeable[2] Cations (Ca, Mg, Na, K)	Not required for samples containing free carbonates or crystals of soluble salts	3.321A	

[1] The methods listed make no mention of automatic C, H, N, and S analysers, specific ion electrodes or ICP units. Methodologies associated with these types of equipment would be acceptable.

[2] Cation exchange capacity and exchangeable cation determinations are done primarily to confirm classification of the soils.

[3] Rhoades, J.D. 1982. Cation exchange capacity. pp. 152-154. In Methods of Soil Analyses, Part 2, Chemical and Microbiological Properties, 2nd Edition. A.L. Page (ed). Published by America Society of Agronomy and Soil Science Society of America, Madison, Wisconsin, USA.

continued . . .

Table 4. Concluded.

Analyses required on selected samples from two representative profiles (A and B horizons) per major map unit and representative samples of parent materials and/or bedrock.

Analyses	Notes	Preferred[1] Method	Acceptable Method
Gypsum[1]	(i) Gypsum may be estimated from the lesser of the Ca or SO_4 concentration in samples having a specific conductance less than 2 mS/cm in the saturation extract. (ii) The 5/1 (solution/soil) ratio recommended in the preferred method may be insufficient to extract all the gypsum present. Use a ratio large enough to produce a filtrate with a specific conductance less than 2 mS/cm.		
Calcium Carbonate Equivalent	Samples may be screened on the basis of pH. Any sample having a $CaCl_2$ pH of 6.5 or greater or any sample having a "water pH" of 7.2 or greater should be analysed for $CaCO_3$.	3.43	Methods of Soil Analyses, Agronomy No. 9[2]
Aluminum and Manganese - Extractable	Not required if sample pH is greater than 5.5 (water pH)	4.64	

[1] Not required in areas where the baseline characterization study indicates that salinity and sodicity could not be a problem.

[2] Black, C.A. et al. 1965. Methods of Soil Analysis, Part 1. Part 2, Chemical and Microbiological Properties, Agronomy No. 9. America Society of Agronomy, Inc., Madison, Wisconsin, USA. Calcium carbonate equivalent - Chapter 91 on Carbonate by L.E. Allison and C.D. Moodie, Acid Neutralization Method (91-4) pp. 1387-1388. Note that the estimate of carbonate provided by this procedure will usually be somewhat high because constituents other than carbonate can react to some degree with the acid utilized.

Table 5. Minimum analytical requirements for disturbed lands and nonselectively handled areas.

Analyses	Notes	Preferred Method[1]	Acceptable Methods
pH	All depths sampled	3.14 or 3.11	3.13
Electrical Conductivity[2]	All depths sampled	3.21	
Saturation Percentage[2]	All depths sampled	3.21	
Soluble Cations (Ca,Mg,Na,K) and SAR[2]	All depths sampled	3.21	
Sulphate	All depths down to 90 cm	Ion Chromatography ICP[3]	Turbidimetric Method[4]
Total Nitrogen	0 to 15 cm	3.622/3.624	3.621/3.623
Organic Carbon	0 to 15 cm	3.611	3.612/3.613
Calcium Carbonate Equivalent	All depths down to 90 cm where $CaCl_2$ pH > 6.5 or water pH > 7.2	3.43	Methods of Soil Analyses, Agronomy No. 9
Particle Size Distribution	All depths sampled	2.11	2.12

[1] McKeague, J.A. 1978. Manual on Soil Sampling and Methods of Analysis. Canadian Society of Soil Science. Ottawa, Canada.

[2] Not required in areas where the baseline characterization study indicates that salinity and sodicity are not a problem.

[3] Ion chromatography or ICP determination of S in water extracts are preferred methods however equipment availability could be a concern.

[4] Turbidimetric Method - One turbidimetric method that can be used is: Greenberg, A.E. (ed). 1981. Standard Methods for the Examination of Water and Wastewater. 15th Edition. Published jointly by American Water Works Association, American Public Health Association and Water Pollution Control Federation. Turbidimetric Method for sulphate. pp. 439-440.

5. CRITERIA FOR EVALUATING THE SUITABILITY OF UNDISTURBED AND RECONSTRUCTED SOILS

5.1 INTRODUCTION

In attempting to establish criteria for evaluating soils and overburden materials, a number of factors must be considered. Invariably, the physical and chemical properties of the soil or overburden are the first to come to mind. However, there is more involved in the establishment and maintenance of vegetation than the properties of the soil. Whitaker (1975) suggests that water, light, carbon dioxide and soil nutrients are most critical to terrestrial production. Furthermore, to optimize plant production in a given environment the factors associated with the soil such as nutrients, water retention and availability must be in balance with all other factors.

Depth criteria are not spelled out in this report - not for unmined soils nor for reconstructed soils. However, occurrence and depth of master horizons (A, B, C) in the predisturbance state has a bearing or influence on how materials are salvaged, with respect to the different lifts involved and subsequently the manner of replacement. Replaced soil thickness should be no more limiting to plant growth than it was in the undisturbed state. Research pertinent to soil handling procedures for disturbed lands in Alberta and elsewhere has been and continues to be done to offer practical procedures and alternatives.

It must be emphasized the thickness replaced depends not only upon soil quality but the quality of the overburden, and other factors such as mean annual precipitation, topography, slope angle, and water table position.

This portion of the report will be organized on the basis of the three major regions of the province as described previously in this document. Each major region implies or suggests some things about climate and soil type. Therefore the materials handling procedures utilized would likely be expected to vary significantly between regions.

Some general procedures for materials handling for each of the regions must be defined in order that suitability criteria can be established or defined. For example, one must suggest topsoil and subsoil are handled separately where appropriate in the Plains Region in order to establish criteria for topsoil and subsoil.

It must be noted each individual area of disturbance has its own unique characteristics, problems and special requirements, therefore, materials handling techniques and soil replacement will be specific to each site. It is also worthwhile to reiterate the criteria which follow can be applied to the pre- and post-disturbance setting.

5.2 PHYSICAL AND CHEMICAL CRITERIA

To evaluate the suitability of soils and overburden materials in a given area one requires a soil survey in sufficient detail is available and that the soils and overburden have been adequately sampled and characterized. The requirement for evaluating reconstructed soil areas would be similar.

Evaluations of soil suitability are made by considering the interaction of various soil properties and characteristics to give an overall rating of the degree of suitability. Three categories of suitability and one category to indicate unsuitable areas are used. The four categories are as follow:

1. Good (G) - None to slight soil limitations that affect use as a plant growth medium.
2. Fair (F) - Moderate soil limitations that affect use but which can be overcome by proper planning and good management.
3. Poor (P) - Severe soil limitations that make use questionable. This does not mean the soil cannot be used, but rather careful planning and very good management are required.
4. Unsuitable (U) - Chemical or physical properties of the soil are so severe reclamation would not be economically feasible or in some cases impossible.

5.2.1 Plains Region

In agricultural areas the selective salvage of topsoil and subsoil and subsequent sequential replacement of these materials is commonly practiced. It is also useful to characterize the material below the subsoil in the predisturbance setting because this usually becomes the "spoil" upon which the reconstructed soils are built. In some instances these parent materials can and do become part of the reconstructed subsoil. To facilitate the identification of suitable sources of soil materials for replacement, it is recommended that the upper five metres be characterized to the level of detail outlined in Section 3.3: Soil Mapping and Sampling.

Topsoil is defined as the surface "A" (organo-mineral) horizons of the soil profile.

Subsoil is defined as the "B" horizon(s) and the upper portion of the parent material.

The criteria for evaluating the suitability of the soils for their use as topsoil and subsoil are listed in Tables 6 and 7.

Table 6. Criteria for evaluating suitability of topsoil in the Plains Region.

Rating/Property	Good (G)	Fair (F)	Poor (P)	Unsuitable (U)
Reaction (pH)	6.5 to 7.5	5.5 to 6.4 & 7.6 to 8.4	4.5 to 5.4 & 8.5 to 9.0	<4.5 and >9.0
Salinity (EC) (dS/m)	<2	2 to 4	4 to 8	>8
Sodicity (SAR)	<4	4 to 8	8 to 12	>12[1]
Saturation (%)	30 to 60	20 to 30, 60 to 80	15 to 20, 80 to 120	<15 and >120
Stoniness Class	S0, S1	S2	S3, S4	S5
Texture	FSL,VFSL, L,SL,SiL	CL,SCL, SiCL	LS,SiC, C[2],S,HC[3]	
Moist Consistency	very friable, friable	loose	firm, very firm	extremely firm
Organic Carbon (%)	>2	1 to 2	<1	
$CaCO_3$ Equivalent (%)	<2	2 to 20	20 to 70	>70

[1] Materials characterized by an SAR of 12 to 20 may be rated as <u>poor</u> if texture is sandy loam or coarser and saturation % is less than 100.

[2] C - May be upgraded to fair or good in some arid areas.

[3] HC - May be upgraded to fair or good in some arid areas.

Table 7. Criteria for evaluating suitability of subsoil material in the Plains Region.

Rating/Property	Good (G)	Fair (F)	Poor (P)	Unsuitable (U)
Reaction (pH)	6.5 to 7.5	5.5 to 6.4 & 7.6 to 8.5	4.5 to 5.4 & 8.6 to 9.0	<4.5 and >9.0
Salinity (EC) (dS/m)	<3	3 to 5	5 to 10	>10
Sodicity (SAR)	<4	4 to 8	8 to 12	>12[1]
Saturation (%)	30 to 60	20 to 30, 60 to 80	15 to 20, 80 to 120	<15 and >120
Stone Content (% Vol)	<3	3 to 25	25 to 50	>50
Texture	FSL,VFSL, L,SiL,SL	CL,SCL, SiCL	S,LS,SiC, C,HC	Bedrock
Moist Consistency	very friable, friable	loose, firm	very firm	extremely firm
Gypsum $CaCO_3$ Equivalent (%)	The suitability criteria for sodicity (SAR) may be altered by the presence of high levels of either lime ($CaCO_3$) or gypsum ($CaSO_4$) in excess of other soluble salts.			

[1] Materials characterized by an SAR of 12 to 20 may be rated as <u>poor</u> if texture is sandy loam or coarser and saturation % is less than 100.

5.2.2 Northern Forest Region

In the Northern Forest Region it is deemed practical to suggest that soil materials be salvaged in two lifts: The upper lift comprising a mixture of the organic and A horizons of the soil solum and perhaps a portion of the B horizon to a depth of about 30 cm depending upon site specific conditions. The second (lower lift) is comprised of the material below the upper lift to a depth deemed appropriate relative to specific site conditions. The second lift need not be salvaged in areas where the overburden material is rated as suitable for use as subsoil or lower lift material. Salvage of the top lift as a separate unit is important in that:

1. Organic matter levels as well as important soil macro- and micro-organisms are less diluted,
2. It generally has better growth support capability, and
3. It may serve as an excellent seed source for some native species.

The criteria for evaluating the soil properties are listed in Tables 8 and 9.

Some explanatory remarks are in order relative to the parameters of stoniness/rockiness and pH and the respective limits included in the suitability rating tables. In severely disturbed environments the presence of stones and coarse fragments can prove to be advantageous in some instances when end land use is anything other than cultivation for production of specific crops. Stones and coarse fragments can provide improved sites for seed germination. Their impact on seedling planting can be controlled to some extent in that seedling planting is generally done with hand tools and planting holes would normally be dug in the less stony spots. Stones and coarse fragments also play an important role in slope stabilization.

In regard to pH, the limits presented are pertinent to an end land use that involves production of trees, primarily conifers. Where the reclamation objective involves an end land use other than forestry, such as erosion control and where other plant species may be more important, then the limits presented in Table 6 are likely to be more applicable.

Table 8. Criteria for evaluating the suitability of surface material (upper lift) for revegetation in the Northern Forest Region.

Rating/Property	Good (G)	Fair (F)	Poor (P)	Unsuitable (U)
Reaction (pH)[1]	5.0 to 6.5	4.0 to 5.0 6.5 to 7.5	3.5 to 4.0 7.5 to 9.0	<3.5 and >9.0
Salinity (EC)[2] (dS/m)	<2	2 to 4	4 to 8	>8
Sodicity (SAR)[2]	<4	4 to 8	8 to 12	>12[3]
Saturation (%)[2]	30 to 60	20 to 30, 60 to 80	15 to 20 80 to 120	<15 and >120
Stoniness/ Rockiness[4] (% Area)	<30/<20	30-50/20-40	50-80/40-70	>80/>70
Texture	FSL,VFSL, L,SiL,SL	CL,SCL, SiCL	LS,SiC, C,HC,S	
Moist Consistency	very friable, friable	loose, firm	very firm	extremely firm
$CaCO_3$ Equivalent (%)	<2	2 to 20	20 to 70	>70

[1] pH values presented are most appropriate for trees, primarily conifers. Where reclamation objective is for other end land uses, such as erosion control, and where other plant species may be more important, refer to Table 6.

[2] Limits may vary depending on plant species to be used.

[3] Materials characterized by an SAR of 12 to 20 may be rated as <u>poor</u> if texture is sandy loam or coarser and saturation % is less than 100.

[4] <25 cm diameter stones/rocks intercepting surface.

Table 9. Criteria for evaluating the suitability of the subsurface material (lower lift) for revegetation in the Northern Forest Region.

Rating/Property	Good (G)	Fair (F)	Poor (P)	Unsuitable (U)
Reaction (pH)[1]	5.0 to 7.0[2]	4.0 to 5.0, 7.0 to 8.0[2]	3.5 to 4.5 8.0 to 9.0	3.5 and >9.0
Salinity (EC)[3] (dS/m)	<3	3 to 5	5 to 8	>8
Sodicity (SAR)	<4	4 to 8	8 to 12	>12[4]
Saturation (%)	30 to 60	20 to 30, 60 to 80	15 to 20 80 to 100	<15 and >100
Coarse Fragments (%/Vol)	<30[5] <15[6]	30 to 50[5] 15 to 30[6]	50 to 70[5] 30 to 50[6]	>70[5] >50[6]
Texture	FS,VFSL, L,SiL,SL	CL,SiC, SiCL	S,LS,S, C,HC	bedrock
Moist Consistency	very friable, friable, firm	loose, very firm	extremely firm	hard rock
$CaCO_3$ Equivalent (%)	<5	5 to 20	20 to 70	>70

[1] pH values presented are most appropriate for trees, primarily conifers. Where reclamation objective is for other end land uses, such as erosion control, and where other plant species may be more important, refer to Table 6.

[2] Higher value takes into consideration that in the lower lift the pH values of the soils are generally higher. Normally the pH rating should not be different from those shown in Tables 9 and 11.

[3] Limit may vary depending on plant species to be used.

[4] Materials characterized by an SAR of 12 to 20 may be rated as <u>poor</u> if texture is sandy loam or coarser and saturation % is less than 100.

[5] Matrix texture (modal) finer than sandy loam.

[6] Matrix texture (modal) sandy loam and coarser.

Organic soils should be considered for salvage and use as a soil conditioner. Origin, degree of decomposition and reaction will determine the suitability of these materials.

5.2.3 Eastern Slopes Region

In the Eastern Slopes Region salvage and replacement of one lift of material is commonly practiced. In this region, as for the Plains and Northern Forested Regions, the material handling procedures will reflect specific site conditions. Current research in Alberta indicates a minimum depth of 15 cm should be considered (Macyk 1982). To facilitate the identification of suitable sources of soil materials for replacement, it is recommended all of the unconsolidated materials be evaluated to the level of detail outlined in Section 3.3: Soil Survey and Sampling.

The criteria for evaluating the soil properties are listed in Table 10.

The comments made relative to stoniness/rockiness and pH in the section of the report dealing with the Northern Forest Region are also applicable to the Eastern Slopes Region.

Table 10. Criteria for evaluating the suitability of root zone material in the Eastern Slopes Region.

Rating/Property	Good (G)	Fair (F)	Poor (P)	Unsuitable (U)
Reaction (pH)[1]	5.0 to 6.5	4.0 to 5.0 6.5 to 7.5	3.5 to 4.0 7.5 to 9.0	<3.5 and >9.0
Salinity (EC)[2] (dS/m)	<2	2 to 4	4 to 8	>8
Sodicity (SAR)[2]	<4	4 to 8	8 to 12	>12[3]
Saturation (%)[2]	30 to 60	20 to 30, 60 to 80	15 to 20, 80 to 100	<15 and >100
Coarse Fragments[4] (%/Vol/Vol)	<30[5] <15[6]	30 to 50[5] 15 to 30[6]	50 to 70[5] 30 to 50[6]	>70[5] >50[6]
Texture	L,SiCL, SCL,SL,FSL	CL,SiL, VFSL,SC,SiC	LS,S Si,C,HC	Consolidated Bedrock
Moist Consistency	very friable, friable	loose, firm	very firm	extremely firm
$CaCO_3$	<2	2 to 20	20 to 70	>70

1 pH values presented are most appropriate for trees, primarily conifers. Where reclamation objective is for other end land uses, such as erosion control, and where other plant species may be more important, refer to Table 6.

2 Limits may vary depending on plant species to be used.

3 Materials characterized by an SAR of 12 to 20 may be rated as poor if texture is sandy loam or coarser and saturation % is less than 100.

4 0.2 to 25 cm diameter fragments in the soil material.

5 Matrix texture (modal) finer than sandy loam.

6 Matrix texture (modal) sandy loam and coarser.

5.3 USE OF THE CRITERIA TO DEVELOP RATINGS

The ratings (good, fair, poor, unsuitable) are determined by assessing the site factors and analytical data in terms of the limits presented in the criteria tables. Each horizon or layer is rated relative to the individual parameters and an overall rating can be developed for each horizon or layer. The most limiting property (rating) determines the ultimate rating for each horizon or layer.

A number of the parameters assessed and used in developing ratings are interrelated. For example, sodicity, saturation percentage and texture are fairly closely related. Therefore, in the event a given soil horizon or layer had a fair rating assessed for each of these parameters and a fair or better rating for the remainder of the parameters considered, the overall rating for that horizon or layer should be fair.

It is important to note some parameters are more important than others in terms of assessing quality and there are those where management practices can overcome or compensate for some limitations. It is not the intent of this document, however, to suggest the extent to which management practice could impact ratings that are developed. Some pertinent comments can, however, be made. For example, a soil could be rated fair, poor, or unsuitable on the basis of degree of stoniness while the remaining parameters considered are not limiting. In this instance it would be reasonable to qualify the rating with a statement to the effect that management practice (stone picking) could be utilized to result in a better soil material.

Examples of how ratings can be developed from site description information and analytical data are presented in the following material. Examples 1 and 2 represent sites prior to disturbance in the Plains and Eastern Slopes Region, respectively. Example 3 represents a reconstructed soil site in the Plains Region.

EXAMPLE 1 (PLAINS REGION)

Soil Group: X
Soil Unit: X1
Classification: Solonetzic Dark Brown
Profile Location: Site 1
Topography: Nearly level
Drainage: Moderately well drained
Parent Material: Till

Description of Representative Profile:

Horizon	Depth (cm)	Colour	Texture	Structure	Consistence	Roots	Stoniness
Ap	0 to 15	very dark grayish brown (10YR 3/2m)	sandy loam	weak fine granular	friable	abundant very fine	S1
Ahe	15 to 25	dark brown (10YR 4/3m)	sandy loam	moderate granular	friable	plentiful very fine	2%
Bnjtj	25 to 45	dark brown (10YR 3/3m)	sandy loam	moderate prismatic	friable	few very fine	2%
Csk	45 to 75	yellowish brown (10YR 5/4m)	loam	-	-	-	5%
Csk	75 to 100	-	loam	-	-	-	5%
Csk	100 to 150	-	loam	-	-	-	5%
Csk	150 to 200	-	loam	-			
Csk	200 to 250	-	loam	-			
Csk	250 to 300	-	loam	-			
Csk	300 to 350	-	silty clay	-			
Csk	350 to 400	-	clay	-			
Csk	400 to 500	-	silty clay	-			

ANALYTICAL DATA

Site: 1 Soil Unit: X1

Horizon	Depth (cm)	pH		Percent Saturation	EC dS/m	Soluble Cations (meq/L)					SAR
		H_2O	$CaCl_2$			Na	K	Ca	Mg	SO_4	
Ap	0 to 15	6.1	5.9	44.0	0.15	0.12	0.13	10.6	0.30	0.36	0.1
Ahe	15 to 25	6.6	6.3	38.5	0.31	1.96	0.05	0.84	0.42	0.72	2.5
Bnjtj	25 to 45	6.9	6.6	53.5	0.24	1.98	0.18	3.2	1.66	0.54	1.3
Csk	45 to 75	7.8	7.6	54.5	0.80	6.52	0.05	1.28	0.74	2.78	6.5
Csk	75 to 100	8.0	7.9	60.0	0.79	6.13	0.08	1.66	0.82	3.00	5.5
Csk	100 to 150	8.2	7.7	54.0	0.71	11.30	0.12	0.84	0.80	5.10	11.5
Csk	150 to 200	7.9	7.6	52.5	0.99	7.65	0.14	1.78	0.66	3.62	6.9
Csk	200 to 250	8.2	7.9	52.5	1.02	8.52	0.17	1.72	0.58	3.46	7.9
Csk	250 to 300	8.0	7.8	51.0	2.71	23.26	0.37	7.00	1.88	13.60	11.0
Csk	300 to 350	8.3	8.0	103.0	1.83	17.61	0.34	2.02	1.00	7.82	14.3
Csk	350 to 400	8.1	8.0	88.5	2.18	21.09	0.38	2.26	0.62	9.38	17.6
Csk	400 to 500	8.0	7.9	77.0	4.43	43.48	0.73	8.40	2.42	25.94	18.7

Horizon	Depth (cm)	Exchangeable Cations (me/100 g)				Cat Exch Capacity meq/100g	$CaCO_3$ Equiv (%)	Part Size Dist (%)			Texture
		Na	K	Ca	Mg			S	Si	C	
Ap	0 to 15	0.01	0.73	9.34	1.98	14.3	-	76	16	8	Sl
Ahe	15 to 25	0.17	0.35	8.69	2.19	13.7	-	69	17	14	SL
Bnjtj	25 to 45	1.83	0.45	5.83	8.68	14.1	-	57	24	19	SL
Csk	45 to 75	-	-	-	-	-	5.81	39	25	26	L
Csk	75 to 100	-	-	-	-	-	5.64	41	35	24	L
Csk	100 to 150	-	-	-	-	-	3.12	45	31	24	L
Csk	150 to 200	-	-	-	-	-	1.08	47	29	24	L
Csk	200 to 250	-	-	-	-	-	1.39	43	33	24	L
Csk	250 to 300	-	-	-	-	-	1.90	46	30	24	L
Csk	300 to 350	-	-	-	-	-	0.91	10	42	48	SiC
Csk	350 to 400	-	-	-	-	-	6.56	13	40	47	C
Csk	400 to 500	-	-	-	-	-	5.23	4	50	46	SiC

SOIL SUITABILITY RATING

Site: 1 Soil Unit: X1

Horizon	Depth (cm)	pH (H_2O)		EC		SAR		% Sat		$CaCO_3$ Equiv		Texture		Consistence		Stoniness		Rating	
		T	S	T	S	T	S	T	S	T	S	T	S	T	S	T	S	T	S
Ap	0 to 15	F	-	G	-	G	-	G	-	G	-	G	-	G	-	G	-	F	-
Ahe	15 to 25	G	-	G	-	G	-	G	-	G	-	G	-	G	-	G	-	G	-
Bnjtj	25 to 45	-	G	-	G	-	G	-	G	-	-	-	G	-	G	-	G	-	G
Csk	45 to 75	-	G	-	G	-	F	-	G	-	-	-	G	-	G	-	F	-	F
Csk	75 to 100	-	G	-	G	-	F	-	G	-	-	-	G	-	G	-	F	-	F
Csk	100 to 150	-	G	-	G	-	P	-	G	-	-	-	G	-	G	-	F	-	P
Csk	150 to 200	-	F	-	G	-	F	-	G	-	-	-	G	-	-	-	-	-	F
Csk	200 to 250	-	F	-	G	-	F	-	G	-	-	-	G	-	-	-	-	-	F
Csk	250 to 300	-	F	-	G	-	P	-	G	-	-	-	G	-	-	-	-	-	P
Csk	300 to 350	-	F	-	G	-	U	-	P	-	-	-	P	-	-	-	-	-	U
Csk	350 to 400	-	F	-	G	-	U	-	P	-	-	-	P	-	-	-	-	-	U
Csk	400 to 500	-	F	-	F	-	U	-	F	-	-	-	P	-	-	-	-	-	U

T - Suitability for use as topsoil material.
S - Suitability for use as subsoil material.
G - Good.
F - Fair.
P - Poor.
U - Unsuitable.

EXAMPLE 2 (EASTERN SLOPES REGION)

Soil Group: Y
Soil Unit: Y1
Classification: Eluviated Dystric Brunisol
Profile Location: 1
Topography: 15 degrees
Drainage: Moderately well drained
Parent Material: Till/Bedrock

Description of Representative Profile:

Horizon	Depth (cm)	Colour	Texture	Structure	Consistence	Coarse Fragments (%/Vol)
L-H	0 to 15	-	-	partially decomposed litter	-	none
Ae	15 to 25	brown (10YR 5/3m)	loam	weak platy	friable	< 5
Bm	25 to 42	dark yellowish brown (10YR 4/4m)	loam	moderate subangular blocky	friable	< 5
BC	42 to 60	olive brown (2.5Y 4/4m)	loam	weak subangular blocky	friable	8
C	60 to 97	very dark grayish brown (10YR 3/2m)	loam	-	friable	15
IIC	97+	very dark brown (2.5Y 3/2m)	sandy loam	-	-	25

ANALYTICAL DATA

Site: Dig 1 Soil Unit: Y1

Horizon	Depth (cm)	pH		Org C %	$CaCO_3$ Equiv (%)	EC dS/m	Exchangeable Cations (meq/100 g)				Cat Exch Capacity meq/100 g
		H_2O	$CaCl_2$				Na	K	Ca	Mg	
L-H	0 to 15	6.3	6.0	38.61	0.0	0.2	0.04	5.43	114.58	10.86	107.0
Ae	15 to 25	5.1	4.2	-	0.0	0.1	0.01	0.38	6.38	2.56	15.9
Bm	25 to 42	5.9	5.2	-	0.0	0.1	0.02	0.17	8.25	2.91	13.0
BC	42 to 60	6.4	6.1	-	0.0	0.2	-	-	-	-	-
C	60 to 97	6.9	6.3	-	0.43	0.1	-	-	-	-	-
IIC	97+	7.3	6.6	-	0.60	-	-	-	-	-	-

Horizon	Depth (cm)	Macronutrients (ppm)[1]				Part Size Dist (%)			Texture	Sand Fractions (%)				
		N	P	K	S	S	Si	C		VCS	CS	MS	FS	VFS
L-H	0 to 15	0	4	68	4.9	-	-	-	-	-	-	-	-	-
Ae	15 to 25	0	11	80	4.1	41	46	13	L	0	3	3	16	20
Bm	25 to 42	0	3	69	-	44	46	10	L	0	4	4	18	18
BC	42 to 60	0	2	81	-	37	43	20	L	0	3	3	16	15
C	60 to 97	0	0	90	-	40	44	16	L	0	2	5	15	18
IIC	97+	0	0	85	-	67	26	7	SL	2	7	9	27	22

[1] These analyses are not required as part of the criteria for assessing suitability.

SOIL SUITABILITY RATING

Site: Dig 1 Soil Unit: Y1

Horizon	Depth (cm)	pH	EC	Coarse Fragments	Texture	Consistence	$CaCO_3$ Equiv	Rating
L-H	0 to 15	Good	Good	Good	-	-	Good	Good
Ae	15 to 25	Good	Good	Good	Good	Good	Good	Good
Bm	25 to 42	Good	Good	Good	Good	Good	Good	Good
BC	42 to 60	Good	Good	Good	Good	Good	Good	Good
C	60 to 97	Fair	Good	Good	Good	Good	Good	Fair
IIC	97+	Fair	-	Fair	Good	-	Good	Fair

EXAMPLE 3 (PLAINS REGION-RECONSTRUCTED SOIL)

Site: Z

Depth (cm)	pH		Percent Saturation	EC dS/m	Soluble Ions (meq/L)				SAR	$CaCO_3$ Equiv (%)	Particle Size (%)			Consistence	Stoniness
	H_2O	$CaCl_2$			Na	K	Ca	Mg			S	Si	C		
0 to 15	6.7	6.3	57.5	0.76	7.35	0.13	1.48	0.84	6.8	0.02	39	38	23	friable	S2
15 to 30	7.8	7.8	73.0	6.39	53.91	0.54	23.00	17.92	11.9	2.58	25	47	28	firm	5%
30 to 45	7.8	7.8	81.5	5.29	39.13	0.58	23.50	17.08	8.7	2.71	20	47	33	very firm	5%
45 to 60	7.6	7.5	69.5	5.16	34.35	0.51	23.75	20.42	7.3	3.73	20	52	28	very firm	5%
60 to 90	7.5	7.3	62.0	2.44	21.96	0.16	5.45	4.00	10.1	1.85	18	41	41	very firm	5%
90 to 120	7.8	7.7	61.0	4.58	36.52	0.37	21.00	9.75	9.3	4.16	39	32	29	firm	5%
120 to 150	8.0	7.7	85.0	4.30	42.61	0.42	11.25	3.63	15.6	2.32	37	32	31	firm	15%
150 to 180	8.2	8.2	165.5	1.59	21.52	0.07	4.10	0.50	43.5	2.16	17	43	40	loose	20%

SOIL SUITABILITY RATING

Site: Z

Depth (cm)	pH(H_2O)		EC		SAR		% Sat		$CACO_3$ Equiv (%)		Texture		Consistence		Stoniness		Rating	
	T	S	T	S	T	S	T	S	T	S	T	S	T	S	T	S	T	S
0 to 15	G	-	G	-	F	-	G	-	G	-	G	-	G	-	G	-	F	-
15 to 30	-	F	-	P	-	P	-	F	-	-	-	G	-	F	-	F	-	P
30 to 45	-	F	-	P	-	P	-	P	-	-	-	F	-	P	-	F	-	P
45 to 60	-	F	-	P	-	F	-	F	-	-	-	F	-	P	-	F	-	P
60 to 90	-	G	-	G	-	P	-	F	-	-	-	P	-	P	-	F	-	P
90 to 120	-	F	-	F	-	P	-	F	-	-	-	F	-	F	-	F	-	P
120 to 150	-	F	-	F	-	U	-	P	-	-	-	F	-	F	-	F	-	U
150 to 180	-	F	-	G	-	U	-	U	-	-	-	F	-	F	-	F	-	U

T - Suitability for use as topsoil material.
S - Suitability for use as subsoil material.
G - Good.
F - Fair.
P - Poor.
U - Unsuitable.

5.4 BIOLOGICAL CONSIDERATIONS

As a result of classic and continually developing knowledge in soil biology, there presently exists a well recognized general appreciation for the importance of the diverse and extensive activities of soil organisms. Tens of thousands of species of bacteria, actinomycetes, fungi, protozoa, nematodes, algae and microfauna have been described and all are known to paly critical roles in soil genesis, cycling and conservation of energy and nutrients and organism/plant associations (Cole et al. 1977; Jones and Woodmansee 1979; McGill and Christie 1981; Fessenden et al. 1981; Silvester 1977). These organisms are not randomly distributed but found in distinct patterns or communities. Such communities vary in degree of complexity and interrelatinship, depending upon characteristics of the soil environment and period of undisturbed development.

Soil biological activity is largely concentrated in the surface horizons of soil as exemplified in Table 11.

This observed decrease in biological activity with increasing soil profile depth closely parallels a similar gradation in soil temperature and moisture as well as availability of O_2 and nutrients. The total biomass of soil organisms in a given soil sample is significant, ranging from 0.06 to 0.2% of sample weight, depending upon sampling site, i.e., semi-arid grassland vs. decomposing forest litter (Domsch et al. 1979, Visser).[1] While some of the fundamental principles in soil biology are now understood, overall comprehension has not reached the point where soil quality criteria, in a biological sense, can be addressed meaningfully or quantitatively. It is very clear, however, that soil chemical and physical properties have a profound influence in determining the composition of a microbial community. In turn, the metabolism of the biological community may dramatically alter the former dynamic equilibrium. Provision of a soil environment meeting suitable

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[1]Visser (Personal Communication).

Table 11. Variation in plate count numbers of selected soil microorganisms with soil profile depth[1].

	Organisms in Dry Soil (Numbers/Grams)		
Soil Profile Depth (cm)	Bacteria (10^6)	Actinomycetes (10^6)	Fungi (10^3)
0 to 15	150.0	35.0	18
15 to 30	62.0	11.0	10
30 to 60	2.5	1.0	4
60 to 90	0.8	0.5	4

(Cook 1968)

[1] Site: Black Chernozem (Malmo Series).

chemical/physical soil quality criteria, therefore, will ensure, in large measure, establishment of balanced, functional populations of soil organisms.

In considering soil organisms within the context of surface reclamation, it is important to recognize that soil organisms will respond to changes in the soil environment resulting in subsequent shifts in the diversity of organisms, population numbers and biochemical activity. The response by soil organisms is relatively immediate and is a sensitive index to change. Thus, potential differences in soil biota existing in a balanced, undisturbed soil versus that found in a drastically disturbed soil are generally acknowledged (Cundile 1977; Curry 1975; Miller 1976; Sindelar et al. 1974). Definitive information in this regard is limited.

Multidisciplined research in soil microbial synecology is currently in progress at a number of locations, for example at the University of Calgary, University of Saskatchewan, Saskatoon, Colorado State University, University of Alberta (Parkinson 1978; Cole et al. 1978; Elliot et al. 1979; McGill and Christie 1981). Such work should prove valuable in attempts to characterize the effects of surface disturbances on soil microbial populations, particularly with respect to the:

1. nature and extent of change in soil microbial populations, for example, the hierarchy of microbial communities and patterns of microbial predation;
2. effect of disturbance on
    - decomposition potential;
    - cycling of trace elements and plant nutrients, particularly C, N, P; and
    - soil development; and
3. effect of disturbance on specialized plant root, microbial relationships such as
    - rhizosphere, rhizoplane associations and mycorrhizal associations.

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7. GLOSSARY

acid soil - A soil having a pH of less than 7.0.

alkaline soil - A soil having a pH greater than 7.0.

amendment soil - (i) An alteration of the properties of a soil, and thereby the soil itself, by the addition of substances such as lime, gypsum and sawdust to it for the purpose of making the soil more suitable for the production of plants, (ii) any such substance used for this purpose.

aquifer - A body of rock that contains sufficient saturated permeable material, to conduct groundwater and to yield economically significant quantities of groundwater to wells and springs.

available nutrient - That portion of any element or compound in the soil that can be readily absorbed and assimilated by growing plants. ("available" should not be confused with "exchangeable").

available water - The part of the water in the soil that can be taken up by plants at rates significant to their growth. Usable, obtainable.

bedrock - The solid rock that underlies soil and the regolith or that is exposed at the surface.

calcareous soil - Soil containing sufficient calcium carbonate (often with magnesium carbonate) to effervesce visibly when treated with cold 0.1 N hydrochloric acid.

clay (soils) - (i) A mineral soil separate consisting of particles less than 0.002 mm in diameter; (ii) a soil textural class; (iii) (engineering) - a fine grained soil that has a high plasticity index in relation to the liquid limit.

coarse texture - The texture exhibited by sands, loamy sands, and sandy loams but not including very fine sandy loam. A soil containing large quantities of these textural classes.

compaction - Increasing the density of a material by reducing the voids between the particles by mechanical effort.

composite sample - A sample comprised of two or more subsamples.

consistency - (i) The resistance of a material to deformation or rupture, (ii) the degree of cohesion or adhesion of the soil mass.

control section - Control section is the vertical section of soil upon which classification is based. For mineral soils in general the control section extends either from the mineral surface to 25 cm below the upper boundary of the C or IIC or to a depth of 2 m, whichever is less. Exceptions are: (a) if the upper boundary of the C or IIC is less than 75 cm from the mineral surface, the control section extends to a depth of 1 m, (b) if bedrock occurs at a depth of less than 1 m, the control section is from the surface to the lithic contact. A lithic contact is the upper surface of a lithic layer which is a consolidated bedrock layer. For organic soils the control section extends from the surface either to a depth of 160 cm or to a lithic contact.

crust - A surface layer on cultivated soils, ranging in thickness from a few millimetres to perhaps as much as 2 cm, that is much more compact and/or hard and brittle when dry, than the material immediately beneath it.

derelict land - Land voluntarily abandoned or willfully cast away by its owner with the intention of not retaking it.

disturbed land - Land on which excavation has occurred or upon which overburden has been deposited, or both.

ecology - A branch of science concerned with the interrelationship of organisms and their environment.

ecosystem - An ecological community considered together with the nonliving factors of its environment as a unit.

environment - The whole complex of climatic, edaphic, and biotic factors that act upon an organism or an ecological community, and ultimately determine its form and survival.

erodibility - A measure of the susceptibility of a soil to particle detachment and transport by rainfall and runoff.

erosion - The general process or the group of processes whereby the earthy and rocky materials of the earth's crust are loosened, dissolved, or worn away, and simultaneously removed from one place to another, by natural agencies that include weathering, solution, corrosion and transportation.

essential element (plant nutrition) - A chemical element required for the normal growth of plants.

fertility, soil - The status of a soil with respect to the amount and availability to plants of elements necessary for plant growth.

fertilizer - Any organic or inorganic material of natural or synthetic origin which is added to a soil to supply certain elements essential to the growth of plants.

fertilizer requirements - The quantity of certain plant nutrient elements needed, in addition to the amount supplied by the soil, to increase plant growth to a designated optimum.

fill - Depth to which material is to be placed (filled) to bring the surface to a predetermined grade. Also, the material itself.

fine texture - Consisting of or containing large quantities of the fine fractions, particularly silt and clay.

ground cover - Any living or dead vegetative material producing a protective mat on or just above the soil surface.

groundwater - That part of the subsurface water that is the zone of saturation, including underground streams. Also called plerotic water; phreatic water.

gully erosion - Erosion of soil or soft rock material by running water that forms distinct, narrow channels that are larger and deeper than rills and that usually carry water only during and immediately after heavy rains or following the melting of ice or snow.

hydraulic conductivity - The rate of flow of water through a given cross section of area under hydraulic gradient at the prevailing temperature.

hydrogeology - The science that deals with subsurface waters and related geologic aspects of surface waters.

impermeability - The condition of a rock, sediment, or soil that renders it incapable of transmitting fluids under pressure.

impervious - Prohibits fluid flow.

infiltration - Water entering the groundwater system through the land surface.

land classification - Classification of specific bodies of land according to their characteristics or to their capabilities for use. A use capability classification may be defined as one based on both physical and economic considerations according to their capabilities for man's use, with sufficient detail of categorical definition and cartographic (mapping) expression to indicate those differences significant to man.

land use planning - The development of plans for the uses of land that, over long periods, will best serve the general welfare, together with the formulation of ways and means for achieving such uses.

leachate - A solution obtained by leaching, for example, water that has percolated through soil containing soluble substances and that contains amounts of these substances in solution.

leaching - The removal of materials in solution by the passage of water through the soil.

micronutrients - A nutrient necessary in small, trace or minute amounts for the growth of plants.

mined-land - Land with new surface characteristics due to the removal of mineable commodities by surface mining methods and subsequent surface reclamation.

mulch - A natural or artificial layer of plant residue or other materials placed on the soil surface to protect seeds, to prevent blowing, to retain soil moisture, to curtail erosion and to modify soil temperature.

mycorrhiza - A unique association generally considered mutually advantageous between the root tissue of higher plants and fungi.

native species - A species which is part of the areas original fauna or flora.

natural revegetation - Natural re-establishment of plants; propagation of new plants over an area by natural processes.

natural seeding (volunteer) - Natural distribution of seed over an area.

neutral soil - A soil in which the surface layer, at least to normal cultivation depth, is neither acid nor alkaline in reaction.

neutralization - The process of adding an acid or alkaline material to water or soil to adjust its pH to a neutral position.

nutrient - A chemical element or inorganic compound taken in by a green plant and used in organic synthesis.

overburden - The earth, rock, and other materials overlying a mineral deposit which must be removed prior to mining.

parent material - The unconsolidated and more or less chemically weathered mineral or organic matter from which the solum of a soil is developed by pedogenic processes.

particle size distribution - The amount of the various soil separates (sand, silt, clay) in a soil sample, usually expressed as weight percentages.

peat - Unconsolidated soil material consisting largely of undecomposed, or only slightly decomposed, organic matter.

percolation - Downward movement of water through soils.

permeability - The measure of the capacity for transmitting a fluid through a substance.

pH - The symbol or term refers to a scale commonly used to express the degrees of acidity or alkalinity. On this scale pH of one is the strongest acid, pH of 14 is the strongest alkali; pH of seven is the point of neutrality.

phytotoxic - Poisonous to plants.

porosity - The volume percentage of the total bulk not occupied by solid particles.

productivity, soil - The capability of a soil in its normal environment for producing a specified plant or sequence of plants under a specified system of management. The "specified" limitations are necessary since no soil can produce all crops with equal success, nor can a single system of management produce the same effect on all soils. Productivity emphasizes the capacity of soil to produce crops and should be expressed in terms of yields.

productive soil - A soil in which the chemical, physical and biological conditions are favourable for the production of crops suited to a particular area.

reclamation - The concept of reclamation of land has been defined as including all desirable and practicable methods for:

(a) designing and conducting a surface disturbance in a manner that minimizes the effect of the disturbance and enhances the reclamation potential of the disturbed lands;
(b) handling surficial material in a manner that ensures a root zone that is conducive to the support of plant growth where required for future use;
(c) contouring the surface to minimize hazardous conditions to ensure stability and to protect the surface against wind or water erosion;

reconstructed profile - The result of selective placement of suitable overburden material on reshaped spoils.

reforestation - The natural or artificial restocking of an area with forest trees.

regrading - The movement of earth to change the shape of the land surface. A finer form of backfilling.

rehabilitation - Implies that the land will be returned to a form and productivity in conformity with a prior land use plan, including a stable ecological state that does not contribute substantially to environmental deterioration and is consistent with surrounding aesthetic values.

revegetation - The establishment of vegetation which replaces original ground cover following land disturbance.

saline soil - A nonalkali soil containing soluble salts in such quantities that they interfere with the growth of most crop plants. The conductivity of the saturation extract is greater than 4 dS/m, the exchangeable sodium percentage is less than 15, and the pH is usually less than 8.5.

sand - A soil particle between 0.05 and 2.0 mm in diameter.

seedbed - The soil prepared by natural or artificial means to promote the germination of seed and the growth of seedlings.

silt - Small mineral soil grains, the particles of which range in diameter from 0.05 to 0.002 mm (or 0.02 to 0.002 mm in the international system).

sodic soil - A soil containing sufficient sodium to interfere with the growth of most crop plants. A soil having an exchangeable sodium percentage of 15 or more.

soil - (i) The collection of natural bodies of the earth's surface, in place, modified or even made by man of earthy materials containing living matter and supporting or capable of supporting plants out-of-doors, (ii) the unconsolidated mineral matter on the surface of the earth that has been subjected to and influenced by genetic and environmental factors of: parent material, climate (including moisture and temperature effects), macro and microorganisms, and topography, all acting over a period of time and producing a product - soil - that differs from the material from which it is derived in many physical, chemical, biological, and morphological properties and characteristics.

soil management - The sum total of all tillage operations, cropping practices, fertilizer, lime and other treatments conducted on or applied to a soil for the production of plants.

soil organic matter - The organic fraction of the soil; includes plant and animal residues at various stages of decomposition, cells and tissues of soil organisms, and substances synthesized by the soil population.

soil profile - A vertical section of a soil which displays all its horizons and its parent material.

soil survey - A general term for the systematic examination of soils in the field and in the laboratories, their description and classification, the mapping of kinds of soil, and the interpretation of soils for many uses, including their suitabilities or limitations for growing various crops, grasses and trees, or for various engineering uses and predicting their behaviour under different management systems; for growing plants and for engineering uses.

spoil - The overburden below the topsoil and subsoil that has been removed in surface mining to gain access to the mineral substance in surface mining.

spoil bank (spoil pile) - Area created by the deposited spoil or overburden material prior to backfilling. Also called cast overburden.

stoniness classes - The classes of stoniness are defined on the basis of the percentage of the land surface occupied by fragments coarser than 15 cm in diameter.
Stone 0 (nonstony) - there are very few stones (0.01% of surface, stones more than 30 m apart).

Stones 1 (slightly stony) - some stones are present that hinder cultivation slightly or not at all (0.01 to 0.1% of surface, stones 10 to 30 m apart).

Stones 2 (moderately stony) - enough stones are present to cause interference with cultivation (0.1 to 3% of surface, stones 2 to 10 m apart).

Stones 3 (very stony) - there are sufficient stones to handicap cultivation seriously; some clearing is required (3 to 15% of surface, stones 1 to 2 m apart).

Stones 4 (exceedingly stony) - the stones prevent cultivation until considerable clearing is done (15 to 50% of surface, stones 0.1 to 0.5 m apart).

Stones 5 (excessively stony) - The land surface is too stony to permit cultivation; it is boulder or stone pavement (more than 50% of the surface, stones less than 0.1 m apart).

strip mine - Refers to a procedure of mining which entails the complete removal of all material from over the product to be mined in a series of rows or strips.

stripping - The removal of earth or nonore rock materials as required to gain access to the ore or mineral materials wanted. The process of removing overburden or waste material in a surface mining operation.

surface soil - The upper portion of arable soils commonly stirred by tillage implements or an equivalent depth (12 to 20 cm) in nonarable soils. That portion of the soil profile occurring at the surface and generally having the highest organic matter content; the A horizon.

synecology - The study of relationships between the environment and the different organisms that make up a biological complex in a single locale. Considered are the various species, the complex

of organisms that make up a biological complex in a single locale. Considered are the various species, the complex of organisms and the association of the assemblage of species with the biologically significant abiotic components of the environment.

tilth - The physical condition of a soil in respect to its fitness for the growth of a specified plant.

topography - The shape of the ground surface, such as hills, mountains, or plains. Steep topography indicates steep slopes or hilly land; flat topography indicates flat land with minor undulations and gentle slopes.

vegetative cover - The entire vegetative canopy on an area.

water table - The surface between the zone of saturation and the zone of aeration; that surface of a body of unconfined ground water at which the pressure is equal to that of the atmosphere.

7.1 REFERENCES FOR GLOSSARY

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